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Kyoichi Kijima
Tokyo Institute of Technology

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Kijima, Kyoichi Jim
Tokyo Institute of Technology

Abstract
An innovative society like an IT-based entrepreneurs society is a competitive society filled with complexity and uncertainty. This paper shows that it is very natural and reasonable that in such an innovative society hierarchy of the networks emerges out to cope with complexity around the intelligent decision makers involved. We develop a rigorous framework, namely, soft game theory, after referring to empirical observations of emergence of two-level networks in Silicon Valley, which inspires this research. We, then, theoretically show that coexistence of both networks and hierarchy is reasonable and inevitable for societies with tight interconnections because it can provide the decision makers with mediation, which is beneficial for the decision makers as well as the society as a whole. Finally, we will go back again to implications from our theoretical study.

Keywords: IT-based Entrepreneurs Society, Hierarchy, Network, Soft Game Theory, Multi-level Systems Theory

1. Introduction

The main purpose of this paper is to analyze why hierarchy of the networks emerges especially in a competitive and innovative IT-based entrepreneurs society. The research is inspired by the observation that in Silicon Valley two-level networks emerge out to cope with complexity around the intelligent decision makers involved. This kind of research on emergence of systemicity, (i.e., hierarchy and network) in a complex system has been one of the most crucial and important problems in systems theory.

We may be able to claim intuitively that hierarchy and complexity seem always associated with each other. Simon, for example, claims that "If there are important systems in the world that are complex without being hierarchic, they may to a considerable extent escape our observation and our understanding" (Simon, 1962).

However, so far we have developed no such a rigorous framework as to formulate the claim and to explore why and how such coexistence of networks and hierarchy emerges. One of the contributions of this paper is that it actually develops and provides an adequate framework where we can discuss this problem rigorously. We believe, in general, that rigorous and, if possible, mathematical, arguments are definitely necessary to obtain solid and deep findings. We hope that the framework of this paper can provide a first step toward formal systems research on the systemisity. Based on the analysis we will point out the fundamental reason of the phenomena is that in an innovative society the agents are tightly interdependent on each other.

In Silicon Valley, California, the entrepreneurs are extremely intelligent, of great confidence and autonomous. They not only have diversified competence but also try to seek powerful and suitable counterparts constantly by appealing their unique talents and ability through the competitive networks.

Indeed, thanks to rapid innovation of information technology, conventional human networks constructed on geographical basis have been complemented by virtual (e.g., internet-based) knowledge networks. They play essential roles especially for the entrepreneurs to ensure their autonomous and quick decision making (Saxenian, 1996). The networks are so tight not only that they literally work as devices for the entrepreneurs to survive against severe competition but also that the reputation or evaluation become immediately and widely well known throughout the society, since the entrepreneurs usually commit themselves to several networks. We have never experienced this kind of speed and amount of information so far.

At the same time, since anonymous people can enter such societies with little barrier if they are intelligent enough, each entrepreneur inevitably has to deal with extreme uncertainty or complexity. He/she may well make mistakes and misunderstand quite often, because of his/her bounded rationality.

In such an innovative and competitive society, some kind of hierarchy of networks emerges for coping with complexity (Saxenian, 1996). That is, some of the agents are motivated to serve as mediators to coordinate other agents in the networks, to form a two-level network society (Refer to Fig. 1). This stratification often occurs almost voluntarily, because their motivation comes not simply from monetary incentive but from their belief emphasizing, say, reputation or trust.

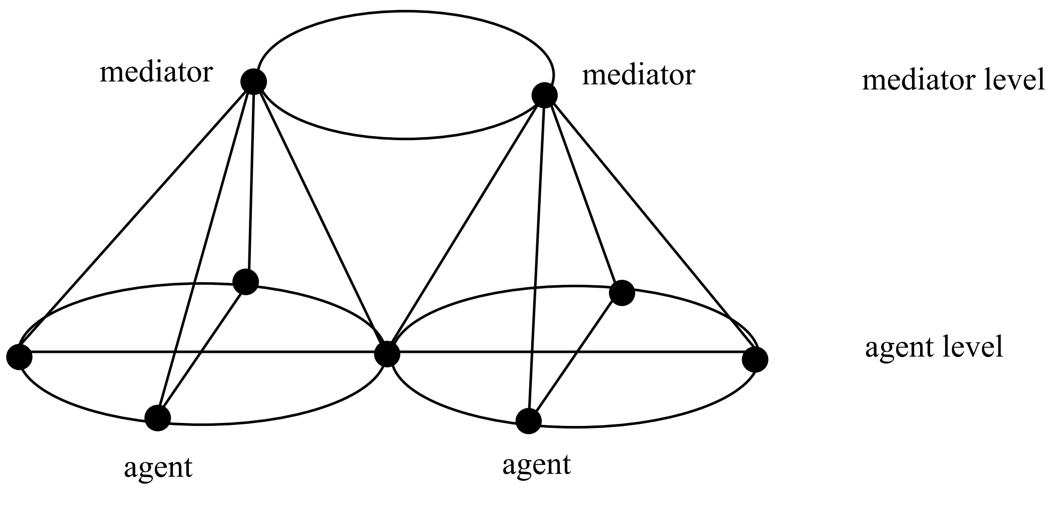

Fig. 1 Two-level Network Society

2. Models of Innovative Society

2.1 Basic Framework

We will tackle the problem by combining soft Operational Research (Checkland, 1981; Rosenhead, 1989) with the multi-level systems theory (Mesarovic, Macko, and Takahara, 1970; Kijima, 1996). Soft Operational Research is Operation Research which particularly focuses on a soft problematic situation, that is, a decision situation involving a variety of agents with diversified and conflicting preference.

An IT-based innovative and competitive society is such a typical soft problematic situation that we can assume the followings legitimately.

(1) It consists of autonomous and intelligent agents. It is assumed that an agent makes decisions for attaining his/her goal by referring to his/her subjective internal model, i.e., a model which he/she subjectively constructs to reflect the environment around him/her (Wonham, 1976). Furthermore, the agents are also supposed to rewrite his/her internal model as well as change his/her concept of rationality through mutual interaction.

(2) The agents' decisions and behavior give immediate and strong impacts on each other.

(3) The agents have to treat so much uncertainty or complexity that they have no time and information to understand the others to a sufficient level. That is, they are always under risk to misunderstand or misperceive their counterparts.
We are particularly interested in Soft Game theory (Howard, 1990), a field of Soft Operational Research, described below in this section to deal with our soft problematic situations.

The multi-level systems theory, on the other hand, is the first, and perhaps the only, attempt to develop mathematical frameworks for conceptualizing such systems, although the importance of multilevel hierarchical systems has been recognized for a long time by philosophers, scientists, engineers, managers, and artists (Auger, 1989). The theory emerged from mathematical system theory and was largely motivated by problems from engineering and management. More than decades after the emergence, this mathematical frameworks were applied to various specific contexts in the sciences of the natural and appropriate theories of multilevel hierarchical systems in these contexts were developed.

2.2 Soft Game Theory

The soft game theory basically identifies four different types of models of decision situations (For more detailed and formal definitions, refer to Kijima, 1996). They are, namely, simple hypergame, symbiotic hypergame, hypergame sharing the same value system and ordinal non-cooperative game, according to the degree and quality of the mutual relationships among the agents, i.e., none, some, consistent and complete. Our main concern is especially with symbiotic hypergame. Since symbiotic hypergame is defined by generalizing simple hypergame, we will begin with simple hypergame.

Simple hypergame formulates a primitive decision situation in the sense that each agent identifies and perceives the decision situation independently though he/she knows he/she participates in the same situation and there is some kind of interaction. The assumptions contrast to those of non cooperative game where each agent is supposed to identify the decision situation commonly or objectively.
Let $I = \{1, 2, \ldots, n\}$ be a fixed set of intelligent agents.

2.2.1 Definition (Simple Hypergame)

A simple hypergame played by I is $\{G_p: p \text{ in } I\}$. Let p be arbitrary in I, then each G_p specifies
(1) S_p, a set of strategies for p,
(2) S_{qp}, a set of strategies which p assumes that q can prepare, where q is another agent in I.

That is, p perceives that q's strategy set is S_{qp}.
(3) p's preference ordering on the outcomes, and
(4) Preference ordering on the outcomes which p assumes that q holds.

Since in simple hypergame situation each agent deals with the situation independently, it is natural to assume that agent p makes decisions by calculating his/her own Nash equilibrium based on G_p. If an outcome is Nash equilibrium of G_p, then p believes that there is no incentive for any of the agents to change his/her strategy as long as the others do not change their strategy.

Next, we define symbiotic hypergame, which will play an essential role when analyzing a competitive network society in the next section. Symbiotic hypergame tries to describe a decision situation where the agents understand that they participate in a common situation but they allow for different ways of identifying the situation. It is defined by associating simple hypergame with interpretation functions which represent how each agent interprets the others' game. That is,

2.2.2 Definition (Symbiotic Hypergame)

A symbiotic hypergame played by I is $\{(G_p, f_{qp}): p \text{ in } I, q \neq p\}$.
In the definition, G_p is a simple hypergame while for each q, where $q \neq p$, f_{qp} is a function from S_p into S_{qp}, which represents how p interprets a strategy q takes in S_q as a strategy in S_{qp}. That is, though p has no idea about what strategy q takes, p believes it should be a particular strategy in S_{qp} by using f_{qp}. We call f_{qp} the interpretation function of p about S_q.

We may consider several ways of defining rationality for dealing with symbiotic hypergame, but the following concept of hyper Nash equilibrium is a natural and straightforward way to define such rationality.

2.2.3 Definition (Symbiotic Nash equilibrium)

Let $(s_1, s_2, \ldots, s_n)$ be an outcome in $S_1 \times S_2 \times \ldots \times S_n$. We call it a symbiotic Nash equilibrium of $\{(G_p, f_{qp}): p \text{ in } I, q \neq p\}$ if each agent, say p, in I interprets it as an outcome which has no incentive to change his/her strategy from s_p as long as p believes that any other agent will not change his/her strategy. That is, a symbiotic Nash equilibrium can be seen as a natural extension of Nash equilibrium by taking into account interpretation by the agents.

In particular, if in hypergame preference of each agent is perceived and interpreted as consistent with his/her own preference, we call it hypergame sharing the same value system.

3. Delphi Mediation of Innovative Society

3.1 Two Options for Dealing with Uncertainty

We easily see that an innovative society can be modeled as a symbiotic hypergame defined in the previous section because we are able to observe the following there.

(1) Each agent is forced to struggle against ignorance and/or uncertainty since he/she can only know about the others' set of strategies and behavior subjectively.

(2) Due to the tight interaction among them, their behavior gives strong and immediate influence on each other.

There are, in principle, two ways available for the agents to cope with extreme uncertainty around them in such a tightly related society. The first is to understand or learn other agents to a sufficient level. By learning the agents collect information about other agents through the networks *horizontally*, but it often costs too much in every aspect. Another way is to introduce mediators to deal with conflicts among the agents. By mediation the agents determine their behavior according to information available *vertically* from the mediators. We may notice that while either network or hierarchy is concept of two dimension, two-level network with mediators is concept of three dimension.

We will show that the latter has great advantage over the former by demonstrating that there is a mediation algorithm which can certainly accommodate the tight interaction among the agents. Owing to the mediation algorithm, each agent can act as if he/she would be independent of others' influence so that he/she devotes himself/herself only to his/her own optimization problem. This optimization is much easier and requires much less information and efforts than problem solving without mediation. We also claim that the reason why we can often see two level networks in an innovative society is that with such two-level networks the agents intentionally or unintentionally use such a mediation algorithm. We call it Delphi mediation algorithm in this paper because of its characteristics.

3.2 Delphi Mediation Algorithm and its Applicability

The Delphi mediation algorithm is mediation procedure named after the well-known Delphi method proposed by RAND cooperation. The Delphi method is a technique to arrive at a group position regarding an issue under investigation. It consists of a series of repeated interrogations, usually by means of questionnaires, of a group of individuals whose opinions or judgments are of interest. After the initial interrogation of each individual, each subsequent interrogation is accompanied by information regarding the preceding round of replies, usually presented anonymously. The individual is thus encouraged to reconsider and, if appropriate, to change his previous reply in light of the replies of other members of the group. After two or three rounds, the group position is determined by averaging.

3.2.1 Definition (Delphi Mediation Algorithm)

The Delphi mediation algorithm is described as follows:
(1) The mediator shows an arbitrary value to each agent as an initial coordination variable. It works as a prediction of other agents' move.
(2) Based on the prediction (or the coordination variable) from the mediator, each agent solves a simple optimization problem under the condition that the others' moves are known.
(3) The agents report their solution to the mediator.
(4) The whole system actually takes actions if the mediator confirms that the reports from all the agents coincide with the prediction. Otherwise, the mediator shows another coordination variable to each agent.
(5) Repeat the above process until the mediator confirms that the reports from all the agents coincide with the prediction.

We should notice that the Delphi mediation algorithm only requires extremely low information processing load, since the mediator is responsible only for checking whether or not the reports coincide with the predication and is not obliged to optimize the whole system. The mediator need not know about interpretation function of any agent, either. This fact gives the agents incentive to play both the roles of mediator and of usual agent, if by doing so they can expect to receive some reputation or trust. Hence, emergence of mediator, or of two-level hierarchy, is very rational from both the viewpoints of the mediator and agents.

Furthermore, the mediation is also beneficial for the society as a whole, as the following theorem shows:

3.2.2 Theorem

Suppose symbiotic hypergame *{(Gp, fqp): p in I, q ≠ p}* has a hyper Nash equilibrium. Then, the Delphi mediation is applicable.

3.3 Practical Implications from the Analysis

Some of implications from the theorem are as follows: First, symbiotic hypergame formulates essential characteristics of an innovative society quite well. In particular, it explicitly describes tight connections and interrelations among the agents in terms of interpretation functions. It clearly contrasts to hypergame, where each agent independently makes decisions and behaves.

The results of the theorem gives us some kind of "feeling of easiness" because it implies even a tightly connected society is "manageable" in the sense that the Delphi mediation algorithm is applicable as far as a Nash equilibrium exists. Indeed, the theorem refers to consistency between rationality for the agents and that for the whole. We may say that agents in an actual innovative society intuitively understand that stratification naturally induces something beneficial to themselves as well to the society as a whole, though they are not exactly sure what kind of mediation is implemented.

4. Conclusions

We showed by using the framework of symbiotic hypergame that emergence of hierarchy of networks is natural and reasonable for a tightly connected innovative society from three view points: The mediator can enjoy reputation without heavy work load while the agents can reduce optimization load. Furthermore, the society as a whole may achieve a kind of rationality if one exists. We also derived some implications from the theoretical arguments and gained insights into the real world.

Both concepts of network and hierarchy, which have been well-developed in systems theory, are of two dimensions. This research suggests that we definitely need a concept of higher order in order, like symbiotic hypergame with mediation, to analyze complexities induced by autonomous agents in innovative society.

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